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ues and busts of Canova, Thorwaldson, Rauch, Gotfried, Rodolph, Schadow, Eberhardt, and other modern sculptors.

We intended to go over the whole ground occupied by the work of Raczyński; for the remainder of the second volume, and the third, abound in matters of the highest interest. But this paper has already extended to such a length, that we must dismiss the subject, at least for the present.

ART. VII. — *Animal Chemistry, or Organic Chemistry in its Application to Physiology and Pathology*. By JUSTUS LIEBIG, M. D., Ph. D., F. R. S., M. R. I. A., Professor of Chemistry in the University of Giessen, &c. &c. Edited from the Author's Manuscript, by WILLIAM GREGORY, M. D., F. R. S. E., M. R. I. A., Professor of Medicine and Chemistry in the University and King's College, Aberdeen. With Additions, Notes, and Corrections, by Dr. GREGORY, and others by JOHN W. WEBSTER, M. D., Erving Professor of Chemistry in Harvard University. Cambridge: John Owen. 1842. 12mo. pp. 347.

THE several kingdoms of nature have each a chemistry of its own. In the mineral or inanimate world, every substance has not only its own mechanical properties to determine its form and mode of existence, but each has its peculiar affinities, which give it its inherent character, and regulate its relations to surrounding objects. These affinities are constant and permanent, and constitute a part of the very nature of the substance; and their actions, under similar circumstances, always produce the same results. By his knowledge of them, the chemist is able to separate the several parts of a compound body, and then, at his pleasure, to restore them again, and reproduce the same, identical substance.

In organic chemistry, an entirely new agency is presented in the principle of life. Without knowing or pretending to know what life is, as an essence, we find it, in its effects, exercising a controlling influence over the properties of matter, in all the operations of organized bodies. At one time it promotes the action of affinity, producing combinations at

a temperature, and under circumstances, in which that, alone, would be inoperative ; at another, it suspends or destroys it, effecting decomposition between bodies strongly united, and appropriating one or the other of them to the purposes of its own organization. In other instances, again, it only modifies the natural affinities of bodies, giving a new character and new properties to the results of the complex action. From a few simple elements are thus formed all the immense varieties of compounds exhibited in the whole range of animal and vegetable life, each having its own essential character, and each capable of being made what it is only by the peculiar organization that formed it. They may be decomposed, their elements detected, and the exact proportions of each element ascertained ; but the whole art of chemistry cannot reconstruct any one of them. The same elements may often be made to unite, sometimes in the same proportions, but the product is totally unlike the original. The simplest vegetable sap, no less than the most complicated animal fluid, although so simple as to seem little more than pure water, and although all its elements are perfectly known to him, contains principles which the chemist has no power to supply. In a few instances, he is able to change one organic product into another, by means of chemical reagents ; but in no case can he produce a like compound out of purely inorganic matter.

In inorganic substances, the principle of action is inherent in the matter itself. When the circumstances are favorable, the action follows of course. In organized bodies, the power of action resides not in the mere matter alone, not even in the organization, neither can it be communicated by any artificial means. It is transmitted from individual to individual, from parent to offspring, each individual transmitting only its own peculiar power. If lost, it is lost for ever, so far as that individual is concerned. Although the organization may seem to our observation to remain perfect, no power short of that of its creation can restore it.

It may easily be seen, then, why the progress of knowledge in this department of chemistry has been much more slow than in others. The investigations that it demands are difficult and often unsatisfactory. The objects examined disappear under the scrutiny, and cannot be recovered for re-examination. And when a new process is instituted, it is not

always easy to produce the same results by similar proceedings. Many of the parts, both of vegetables and animals, are so volatile and evanescent, that they escape from observation, almost before the examination is begun; others so readily yield to different forms of combination, that it is not easy to be assured, that the compound analyzed by the chemist is always the same that has circulated in the living body.

Yet not a little has been done, especially in the details of this branch of chemistry. The composition of a very large number of organic substances, both animal and vegetable, has been carefully ascertained, both in their proximate principles, and in their ultimate constituents. And, although much remains unknown, which we may strongly desire to know, something is known of the uses of the several principles in their appropriate economy, and of the reciprocal influence of foreign substances upon them. But no general exposition of all the chemical operations in the growth and sustenance of animals and vegetables, applicable to all their multiform functions, has, we believe, ever before been attempted; certainly none has succeeded in obtaining the approbation and sanction of the scientific world in general. The present work of Professor Liebig, in connexion with his previous Report, and one that is to follow, aims and professes to do this. How far he has succeeded in accomplishing it, remains to be seen, and we proceed to inquire.

The inquiries of Professor Liebig were undertaken in consequence of a request of the chemical section of the British Association for the Advancement of Science. His first Report, on "Organic Chemistry in its Application to Agriculture and Physiology," was presented to that body in 1840. The second Report on "Organic Chemistry in its Application to Physiology and Pathology," has been prepared for the meeting of the present year, and has been published, before being communicated to the body of its special patrons. A third Report is promised, to contain the author's researches into the nature of the food of man and animals, and of the changes which it undergoes in its preparation for use by cooking.

The previous reputation of the author, as a zealous and able analytical chemist, appears to have excited very high expectations of the value of the work that he was to produce, and to have prepared the way for the enthusiastic reception it met with. Professor Gregory declared, in the

British Association, as we are informed in the Preface to the American Edition, "that the Association had just reason to be proud of such a work, as originating in their recommendation ;" and Professors Lindley, Daubeney, and others, concur in regarding the date of its publication "as the commencement of a new era in the art of agriculture." One of the Copley medals, of the Royal Society of London, was presented to the author the same year. The President, the Marquis of Northampton, in presenting the medal to Professor Liebig's representative on the occasion, said, "My principal difficulty, in the present exercise of this the most agreeable part of my official duty, is to know, whether to consider M. Liebig's inquiries as most important in a chemical or a physiological light." If his Lordship will honor our Review with a careful perusal, we think he may be relieved of a part of his difficulty.

This second Report is announced with the same flourish of trumpets. The American editor declares the author to be, without question, the first living authority in Organic Chemistry ; and the translator, Dr. Gregory, has "experienced the highest admiration of the profound sagacity, which enabled the author to erect so beautiful a structure on the foundation of facts, which others had allowed to remain for so long a time utterly useless," and regards its appearance as "the commencement of a new era in physiology." We have thus, already, two new eras, a new era in agriculture, and a new era in physiology ; and some two years hence, when the third Report shall be forthcoming, we shall doubtless have a new era in the art of dieting and cookery.

It cannot be doubted, that institutions for the advancement of science, upon the plan of the British Association, may do much, and have done something, for the dissemination of knowledge. They may, also, to a considerable extent, excite a spirit of investigation. But it remains to be proved, and may well be questioned, whether their influence is more favorable to profound research, than the old-fashioned way of more private study and observation. Scientific discussions before large audiences of ladies and gentlemen, learned and unlearned, public assemblies, public promenades, and public dinners, may serve a very good purpose to render science popular ; but they have no great tendency to increase its

depth. It is true, that the investigations are made, and the report of them is written, in seclusion ; but the constitution of the body, before which the Report is to be read, and under whose auspices it is to be ushered into the world, cannot fail to exert a powerful influence upon its character. And how different will be the influence, if that body be a large and brilliant assemblage of fashionable patrons of learning, with a sprinkling of men of learning, from what it would be if these same learned men were quietly gathered by themselves in some private hall. Such were our older *academies* of science ; the former is the modern *association*.

Professor Liebig himself participates in the complacency with which his works are regarded by his admirers. His opinions are often given with a confidence which savours, not a little, of dogmatism ; and he is not always careful to mention the attainments and labors of others with all the respect, that may reasonably be demanded from a candid searcher after true knowledge. For example, he repeatedly speaks of “pretended experiments,” and “experiments that teach nothing,” for no other reason, that is exhibited, than that they were not favorable to his conclusions ; and this, too, while his own observations are referred to only by their results, without any details to enable the reader to judge of their accuracy or sufficiency. He demands a confidence from his readers, which he is not willing to render to others. He enters, apparently for the first time, into the field of physiology, with a feeling nearly allied to contempt for the attainments of all its previous cultivators. The following language is used in the first Report.

“All discoveries in physics and in chemistry, all explanations of chemists, must remain without fruit and useless, because, even to the great leaders in physiology, carbonic acid, ammonia, acids, and bases are sounds without meaning, words without sense, terms of an unknown language, which awaken no thoughts and no associations. They treat these sciences like the vulgar, who despise a foreign literature in exact proportion to their ignorance of it ; since, even when they have had some acquaintance with them, they have not understood their spirit and application.

“Physiologists reject the aid of chemistry in their inquiry into the secrets of vitality, although it alone could guide them in the true path ; they reject chemistry, because, in its pursuit of

knowledge, it destroys the subjects of its investigation ; but they forget, that the knife of the anatomist must dismember the body, and destroy its organs, if an account is to be given of their form, structure, and functions." — *Report on Vegetable Chemistry*, p. 86.

To our medical readers, if indeed to any, we surely need not say, how far this is from being true. Chemistry constitutes a full proportional part of the course of instruction in all medical schools ; and we believe it holds good everywhere, as it certainly does in this country, that, with the exception of those who make it their especial business, either as teachers, or as engaged in the chemical arts, there is much more acquaintance with it, as a branch of learning, among physicians, who, of course, are the only physiologists, than in any other class of scientific men. When chemistry first revived, in the days of Priestley, Lavoisier, Fourcroy, and their contemporaries, the wonderful discoveries, that were made by them, were eagerly and zealously applied to the explanation of a great variety of phenomena in animal and vegetable life ; driving out of vogue the multiplied forms of the mechanical theories of previous times. But it soon became apparent, that some of the explanations, thus introduced, were insufficient and unsatisfactory. And, from that day to this, the influence of merely chemical theories in physiology has been undergoing an almost constant reduction of its limits. It is possible, indeed, that this reaction may have gone too far ; but of this we shall judge better hereafter.

It would almost seem, that our author, in preparing himself to apply his knowledge of chemistry to illuminate the darkness of physiologists, had only consulted recent elementary writers, and had overlooked the opinions of their predecessors ; that he began his *cramming* at too late a period. Theories, that were in full credit forty years ago, and have since fallen into the mere history of science, are, in some instances, brought forward, and urged with great earnestness, without any intimation or appearance of suspicion, that they have ever been heard of before. There are other indications of a recent and imperfect knowledge of the functions, and even of the structure, of the animal body. Some of these may possibly arise from typographical errors or incorrect translation ; and two or three are corrected as such in a table of *errata* in the Cambridge

edition, although they certainly have much the appearance of original misconception.* Others, however, will scarcely admit of such an explanation; as when we are told (p. 57), that "the venous blood, before reaching the heart, is made to pass through the liver; the arterial blood, on the other hand, passes through the kidneys; and these organs separate from both all substances incapable of contributing to nutrition." And again (p. 213), "The substance of cellular tissue, of membranes, and of the skin, the minutest particles of which are not in immediate contact with arterial blood (with oxygen), are not destined to undergo this change of matter. Whatever changes they may undergo in the vital process, affect, in all cases, only their surface." From this and similar remarks, it is obvious, that the author supposes all the membranous and tendinous parts, including the cellular membrane, the skin, &c., to be destitute not only of a true circulation, but also of nerves!

In the purely chemical parts of the work, we give to the author our unreserved confidence; in the accuracy of all his statements, at least, if not in the soundness of his theories. The first Report is in a great degree speculative; made up of reasonings on facts already known, but now applied in new relations to the support of the author's views; not without a considerable addition of new observations, the result of his own researches. The second contains a much larger proportion of original information, and savours more of the laboratory. The analyses which are given of many portions of animal organization, attach a high degree of value to the work, whatever may be thought of the speculations by which they are accompanied.

We have on former occasions commended the agricultural

* The following passage affords an example of the kind referred to. Either with or without the correction, it exhibits but a confused idea of the phenomena of emphysema from injury. "It is known, that in cases of wounds of the lungs a peculiar condition is produced, in which, by the act of inspiration, not only oxygen but atmospherical air, with its whole amount (four fifths) of nitrogen, penetrates into the cells of the lungs. This air is carried by the *circulation* [corrected in the list of *errata* to *cellular tissue*] to every part of the body, so that every part is inflated or puffed up with the air, as with water in dropsy. This state ceases, without pain, as soon as the entrance of the air through the wound is stopped. There can be no doubt that the oxygen of the air, thus accumulated in the cellular tissue, enters into combination, while its nitrogen is expired through the skin and lungs." — p. 110.

portion of the first of these works, and spoken of its tendency to introduce important improvements in the methods of culture ; without going fully into an examination of the author's peculiar views in regard to the growth and nourishment of plants.* But the physiology of vegetable life is so intimately connected with that of animals, that it is scarcely possible to obtain correct notions of either, without some knowledge of the other. The two Reports are essentially parts of one work ; and, in order to gain a just apprehension of their true merits as a philosophical treatise, or to acquire a full impression of the author's opinions, they should be examined together. Before we proceed further, therefore, in our consideration of the second Report, we will take a brief notice of that part of the first, which relates to the physiology of vegetables. And, if we should find reason to be less satisfied with our author's physiological opinions than we were with his agricultural precepts, it would not be the first time that a man of great practical acuteness has been tempted to his hurt into fields of speculation, for which his previous habits and studies have not fitted him.

The chief elements of vegetable matter are carbon, oxygen, and hydrogen. Of the woody fibre, and many other portions of plants, these three substances are the sole constituent principles, and of every portion of every plant, they constitute by far the greater part. Nitrogen, and a few other substances, enter in some small proportion into the composition of certain parts, and the amount of these varies not a little in different plants, and in the same plants under different circumstances. It is regarded by Professor Liebig as a distinguishing feature between plants that grow spontaneously, and those raised under the influence of artificial cultivation, that the latter contain a much larger proportion of those vegetable compounds, or *proximate principles*, which contain nitrogen, than the former. Much of his theory of culture is founded upon this distinction ; it being a leading object with him to furnish to plants under cultivation a sufficient abundance of substances, that shall afford nitrogen in a condition to facilitate its absorption.

The composition of plants being thus simple, it is obvious, that a primary object of inquiry in regard to their growth and

* See *North American Review*, Vol. LIII., p. 147, *et seq.* ; LIV., p. 476, *et seq.*

sustenance, is to learn the source from which these elements are obtained, and the means by which they are incorporated into the plant. Professor Liebig conceives, that the carbon is derived exclusively from the carbonic acid of the atmosphere, and the oxygen and hydrogen chiefly, and the nitrogen and other matters exclusively, from the soil. Now, fully one half of all vegetable substances is made up of carbon, and the proportion of carbonic acid (of which less than one third is carbon) in the atmosphere, according to Professor Liebig, is one thousandth; while the nitrogen in plants rarely exceeds one or two per cent., very often much less, and four fifths of the whole atmosphere is pure nitrogen gas. On the other hand, the portion of the soil, which, under the names of *humus*, *ulmin*, *geine*, &c., is regarded by all chemists as indispensable to the free growth of plants, contains, in different specimens, from 57 to 72 parts in a hundred of carbon, and, as a constant element, no nitrogen. Even Professor Liebig himself appears to regard the presence of nitrogen as a sort of accidental infiltration in the form of ammonia, or as the effect of culture. Under these circumstances, it seems highly improbable, to say the least of it, that each of these bodies should be supplied only from the most limited source, to the neglect of that which is so abundant. No reason appears on the face of things, why the reverse should not be true, — the carbon supplied by the soil, chiefly if not entirely, and the nitrogen by the atmosphere.

The only reason given by Professor Liebig, for believing that the nitrogen of plants is not derived from the atmosphere, is that “the nitrogen of the air cannot be made to enter into combination with any element except oxygen, even by employment of the most powerful chemical means.” (p. 126.) It is strange, that he should have forgotten that the same thing is no less true of the carbonic acid of the air. Carbonic acid in the aëriform state we believe has never been decomposed by artificial means; and, when the gas is in its nascent state, or when the acid is fixed by combination with a base, the oxygen can be separated only by very strong affinities, aided by a temperature not less than that of a red heat. Even the oxygen and hydrogen, which have so strong an affinity for each other, combine only at the temperature of ignition. Indeed, there are none of the chief elements of plants, that can

be made by any artificial chemical means to combine at the ordinary temperature of growing vegetables.

A similar reason is given for denying that carbon is absorbed from the soil by the roots of plants.

“Vegetable physiologists agree in the supposition, that by the aid of water *humus* is rendered capable of being absorbed by the roots of plants. But, according to the observation of chemists, humic acid is soluble only when newly precipitated, and becomes completely insoluble when dried in the air, or when exposed in the moist state to the freezing temperature. Both the cold of winter and the heat of summer, therefore, are destructive of the solubility of humic acid, and at the same time of its capability of being assimilated by plants. So that, if it is absorbed by plants, it must be in some altered form.”

“These facts, which show that humic acid in its unaltered condition cannot serve for the nourishment of plants, have not escaped the notice of physiologists; and hence they have assumed, that the lime or the different alkalies, found in the ashes of vegetables, render soluble humic acid, and fit it for the process of assimilation.” — *Vegetable Chemistry*, pp. 63, 64.

Professor Liebig then goes into an extended calculation, of several pages, to show, that the amount of alkalies and alkaline earths contained in any given quantity of vegetable matter, is altogether insufficient to combine with and render soluble humic acid enough to supply the carbon which the same vegetable contains. All this may be true; it matters not. But he overlooks the fact, that living plants have a power of appropriating matter to themselves, independently of any known laws of affinity. We have already seen this in regard to several of the gases. It is no less true in respect to liquids and solids. Some of the grasses, which are among the simplest of vegetables, select and take up silex, one of the hardest and least soluble of the earths, and incorporate it into their texture to such an extent, that they will strike fire with steel. Nay, we are assured, on high chemical authority,* that, when made to grow in distilled water in a glass vessel, they will decompose the surface of the glass, and appropriate both the silex and the alkali, of which it is composed, to their own growth. It must have been in the observation of many persons, who cultivate ornamental bulbous roots in glasses, that the inner surface of the glass loses its polish, and becomes

* Dr. C. T. Jackson.

rough. This is merely from the decomposition of the glass. Now water alone will produce no such effect on glass. The living plant communicates by its roots, through the water (for the roots are generally not in contact with the glass), an influence powerful enough to separate the potash of the glass from its strong combination, and transfer it to itself. With the knowledge of such facts in our view, we are not left to the necessity of rejecting a belief in the existence of any process in vegetable life, merely because it cannot be explained by the laws of inorganic chemistry.

Very early after the true nature of the principal gases became known, it was discovered, that carbonic acid is absorbed by the leaves of plants, and that oxygen gas is given out in the place of it. At a later period this was denied, and the reverse was asserted, that plants, like animals, consume oxygen and produce carbonic acid. It turns out, that both statements are true, under different circumstances. In a bright sunlight, oxygen is given out from the leaves, and carbonic acid disappears; in the darkness of night, the oxygen of the surrounding air is diminished, and the carbonic acid is increased. Professor Liebig claims, that the first only is a true vital process; that the proper function of the plant is performed only during the day, in the absorption of carbon, and thus setting free the oxygen; and that in the night, the vital force, being weakened by the absence of light, is not able to prevent the oxygen of the air from acting chemically on some of the vegetable principles contained in the leaves, and combining with them so as to form the carbonic acid. This is a mere assumption. No good reason can be given for regarding one as any less a chemical process than the other. We believe, that both are equally under the influence of the living powers of the plant, acting in these, as in other cases, by the agency of chemical affinities whenever they are of a nature to subserve the purposes of its organization, and annulling them whenever they are adverse. If it were not so, there must be a conflict of powers, that would sometimes produce strange confusion in the organic world. Besides, plants do not cease to grow in the night; some grow extensively and rapidly without light. Whence do they, then, obtain their carbon?

The belief, that oxygen gas is set free in the atmosphere by the growth of plants, was long ago regarded with favor, as

furnishing a compensation for the consumption of oxygen, or rather its transformation into carbonic acid, by the respiration of animals. Preachers and philosophers have united in hailing it as an example of the wisdom of the Creator, in establishing so beautiful a provision for the perpetuity of his work. Professor Liebig adopts the same view of the matter, and enlarges upon it. He says ;

“ Although the absolute quantity of oxygen contained in the atmosphere appears very great when represented by numbers, yet it is not inexhaustible. One man consumes by respiration 45 Hessian cubic feet of oxygen in 24 hours; 10 centners of charcoal consume 58,112 cubic feet of oxygen during its combustion ; and a small town, like Giessen (with about 7000 inhabitants), extracts yearly from the air, by the wood employed as fuel, more than 1000 millions of cubic feet of this gas.” — p. 70.

This remark is followed in a note by a calculation for ascertaining the length of time that the atmosphere would sustain the world with its present amount of oxygen. The result is, that, if there were no means of replacing it, a thousand million men would use up all the oxygen in three hundred and three thousand years. The appendix to the American edition repeats the calculation with a result somewhat more favorable to the hopes of the world. It there appears, that to reduce the proportion of oxygen in the atmosphere twelve per cent., below which it will not sustain animal life, a thousand million men must breathe it away a full million of years. We have not taken the trouble to review these calculations. Either carries the fatal period of universal extermination so far off, as to leave us no great cause of alarm for the safety of the present generation.

Professor Liebig proceeds ;

“ When we consider facts, such as these, our former statements, that the quantity of oxygen does not diminish in the course of ages, — that the air, at the present day, for example, does not contain less oxygen than that found in jars buried for 1800 years in Pompeii, — appears quite incomprehensible, unless some source exists whence the oxygen abstracted is replaced. How does it happen, then, that the oxygen in the atmosphere is thus invariable ?

“ The answer to this question depends upon another ; namely, what becomes of the carbonic acid, which is produced during the respiration of animals, and by the process of combustion ?

A cubic foot of oxygen gas, by uniting with carbon so as to form carbonic acid, does not change its volume. The billions of cubic feet of oxygen extracted from the atmosphere produce the same number of billions of cubic feet of carbonic acid, which immediately supply its place." — pp. 70, 71.

"It has been already mentioned, that carbon and the elements of water form the principal constituents of vegetables; the quantity of the substances which do not possess this composition being in very small proportion. Now, the relative quantity of oxygen in the whole mass is less than in carbonic acid. It is therefore certain, that plants must possess the power of decomposing carbonic acid, since they appropriate its carbon for their own use. The formation of their principal component substances, must, necessarily, be attended with the separation of the carbon of the carbonic acid from the oxygen, which must be returned to the atmosphere, whilst the carbon enters into combination with water or its elements. The atmosphere must thus receive a volume of oxygen for every volume of carbonic acid which has been decomposed." — p. 72.

This theory of compensations, however plausible or beautiful it may appear at first sight, has, on examination, very little to sustain it. The Creator of the universe has not left the perfection of his work dependent on accidental contingencies, — on the greater or less prevalence of animal or vegetable life. Not only is the composition of the air unchanged, within all known periods of time, but it is also the same in every part of the globe; — the same in the middle of the ocean, on the heights of Chimborazo, on the Peak of Teneriffe, as in the most crowded city. If the supposed causes were sufficient to exert any appreciable influence, that influence ought to be as unequally distributed as the cause.

Again, if the growth of plants is necessary to replace the oxygen respired by animals, when the atmosphere contains twenty-one parts in a hundred of oxygen gas, how much more necessary must be the presence of animals to supply carbon for vegetation, since the air contains only a three thousandth part of it. But Geology teaches, indisputably, that, for a long period of time, the earth was covered by a luxurious vegetable growth, before any animal made its appearance on the globe. What animals expired the carbonic acid for the carbon of all the mines of coal with which the earth teems? These masses of coal were once living plants, and, if our author's theory be true, must all have floated in

the atmosphere as carbonic acid, long before any animal was seen on the face of the earth.

The true view of the case, however, has no respect to any of these suppositions. No new matter is created with the progress of the world. Its forms and relations are changing perpetually ; but its elements remain the same, in all their combinations. All the forms, and all the products, of organic life have a constant tendency to return spontaneously, to dissolve, into their natural elements. Men and animals die, and return to their dust. And, although we are unable to trace all the steps by which the particles of matter, that compose them, are restored to their previous state of existence, there is no reason to doubt, that the restoration is complete. As generation after generation has passed away, the constituent parts of each have resumed the forms that before belonged to them, or have entered into new combinations, according to their relation to objects around them.

Plants, too, die and decay. And here we are able to point out the steps of their decomposition ; so far, at least, as to see that whatever oxygen may have been liberated by the assimilation of carbon, is necessarily recombined, whenever either by combustion or decay that carbon is again converted into carbonic acid. In the long progress of ages, there is as much of combustion and decay, as of growth, in the vegetable world ; and, consequently, just as much oxygen is consumed in the one process, as is set free in the other. Where, then, is the surplus, to supply the exhaustion supposed to be occasioned by the respiration of animals ?

These considerations do not decide the question, whether carbon is, or is not, absorbed from the atmosphere into the substance of living vegetables. But they relieve the subject from extraneous influences, and leave the question to be settled by its own proper evidence. We have no doubt that plants do derive a portion of their carbon from the air ; but we are not at all convinced, that the whole, as Professor Liebig supposes, is thus obtained ; or that even the chief portion is from this source. When we see a supply so much more abundant in the soil, and in a form, which, whatever may be its mode of action, all agree is indispensable to vegetable growth, we cannot suppose that its presence there is for a purpose so subordinate as our author would have us believe.

We return to the second Report.

Professor Liebig treats of his whole subject as if it were a matter of course, that all difference of properties, in the products of organized matter, whether vegetable or animal, necessarily implies a difference of composition ; and the converse, that identity of composition indicates identity of properties. A "change in the properties of the living compound" is with him the same thing as "a change of matter." (p. 201.) He produces no evidence of this. He scarcely even states it as a distinct proposition. But almost the whole course of his reasoning proceeds upon the assumption of its truth. And yet there not only is no proof that it is true, but there is much that it is not so. Matter, even in its simpler modes of existence, is often found in different forms, without any change of composition. The several forms of solid, liquid, and gaseous, exhibit, surely, very different properties, in consequence merely of the absorption of heat. The properties of ice cannot be regarded as the same with those of water or steam. We may be told, perhaps, that here is a new combination with the caloric. This supposition is purely hypothetical. But there are cases, which do not admit even of this explanation. The elementary substance carbon, for example, is found in three distinct forms, varying greatly in their whole appearance and properties, yet each of them proves, on the most perfect analysis, to be pure carbon ; namely, charcoal, graphite, and diamond. In the more complicated compounds of organized matter, there are numerous instances of this kind. Thus, the composition of sugar is identical with that of gum ; yet no spinster would mistake, in her tea, a piece of tragacanth for a lump of East Boston triple-refined. Professor Liebig notices the existence of *isomeric* compounds, as they are called, but he offers no explanation in regard to them, and seems not to perceive how much they are at variance with the whole scope of his observations and reasoning.

He also takes it for granted, and with no more of proof in this case than in the other, that what have been called the peculiar principles of vegetables, exert precisely the same influence on the animal body, as the individual articles from which they are obtained. Thus, coffee and tea have both the same effect on the system, because *caffeine* and *theine*, the essential principles of each, are identical in their composition. Hear this, ye sighing vale-

tudinarians, who are gasping to learn of every physician ye meet, which of these luxurious "poisons" is the least "wholesome"; and learn, for your comfort (or your confusion), that they are neither more nor less than the same thing. One may grow only in China, the other in India or America, or wherever else it will; one may be a leaf, the other a berry; one may be a simple infusion, the other roasted, and tortured, and boiled; it matters not, their effects are the same. And, if they do not look alike, and smell alike, and taste alike, it is not the fault of chemistry; for caffeine and theine each contains eight atoms of carbon, five atoms of hydrogen, two atoms of nitrogen, and two atoms of oxygen.

We come now to the leading feature of Professor Liebig's system of physiology; that upon which his claim to distinction, as the founder of a "new era" in science, is to rest, his chemical theory of life. According to this theory, every action of the living body, animal or vegetable, is not only accompanied, but is caused, by a change of chemical composition; every action is the immediate effect of a truly chemical process. Professor Liebig, indeed, recognises a "vital force," which exerts some sort of influence in giving a character and direction to the chemical agencies. But it is not always easy to see, exactly, how much importance he would attach to this; for either his own opinions about it are very confused, or he has expressed them very obscurely. It is quite clear, however, that he regards chemical action as the chief point of interest, and almost the only object of investigation. If it does not actually originate the vital force itself, it is the sole cause of its activity. Even the slightest motion of a finger occasions a chemical decomposition of a portion of the muscles employed. He says,

"The most ordinary experience further shows, that at each moment of life, in the animal organism, a continued change of matter, more or less accelerated, is going on; that a part of the structure is transformed into unorganized matter, loses its condition of life, and must be again renewed. Physiology has sufficiently decisive grounds for the opinion, that every motion, every manifestation of force, is the result of a transformation of the structure or of its substance; that every conception, every mental affection, is followed by changes in the chemical nature of the secreted fluids; that every thought, every sensation, is

accompanied by a change in the composition of the substance of the brain." — p. 8.

Our author's idea of life is thus described.

"In the animal ovum, as well as in the seed of a plant, we recognise a certain remarkable force, the source of growth, or increase in the mass, and of reproduction, or of supply of the matter consumed; a force in a state of rest. By the action of external influences, by impregnation, by the presence of air and moisture, the condition of static equilibrium of this force is disturbed; entering into a state of motion or activity, it exhibits itself in the production of a series of forms, which, although occasionally bounded by right lines, are yet widely distinct from geometrical forms, such as we observe in crystallized minerals. This force is called the *vital force*, *vis vitæ*, or *vitality*.

"The increase of mass in a plant is determined by the occurrence of a decomposition, which takes place in certain parts of the plant under the influence of light and heat." — p. 1.

The vital force, or life, is of two kinds, *animal* and *vegetative*. The first is derived solely from the brain and nervous system, and regulates all the motions of the animal body. The second is independent of the nervous system, but exists in animals no less than in plants, and is found in the parts concerned in the growth and nutrition of the body, and in the secreting organs.

"Every thing in the animal organism, to which the name of *motion* can be applied, proceeds from the nervous apparatus. The phenomena of motion in vegetables, the circulation of the sap, for example, observed in many of the characeæ, and the closing of flowers and leaves, depend on physical and mechanical causes. A plant is destitute of nerves. Heat and light are the remote causes of motion in vegetables; but in animals we recognise in the nervous apparatus a source of power, capable of renewing itself at every moment of their existence." — p. 3.

"Assimilation, or the process of formation and growth, — in other words, the passage of matter from a state of motion to that of rest, — goes on in the same way in animals and in vegetables. In both, the same cause determines the increase of mass. This constitutes the true vegetative life, which is carried on without consciousness." — p. 4.

Let it not be supposed, from these passages, that the author ascribes to the vital force any controlling power over the actions of the living body. On the contrary, he regards

it as altogether subordinate to chemical agencies. He goes on to say,

“ It cannot be denied, that this peculiar force exercises a certain influence on the activity of vegetative life, just as other immaterial agents, such as Light, Heat, Electricity, and Magnetism do ; but this influence is not of a determinative kind, and manifests itself only as an acceleration, a retarding, or a disturbance of the process of vegetative life. In a manner exactly analogous, the vegetative life reacts on the conscious mental existence.” — p. 5.

And again,

“ Viewed as an object of scientific research, animal life exhibits itself in a series of phenomena, the connexion and recurrence of which are determined by the changes which the food and the oxygen, absorbed from the atmosphere, undergo in the organism under the influence of the vital force.

“ All vital activity arises from the mutual action of the oxygen of the atmosphere and the elements of the food.

“ In the processes of nutrition and reproduction, we perceive the passage of matter from the state of motion to that of rest (static equilibrium) ; under the influence of the nervous system, this matter enters again into a state of motion. The ultimate causes of these different conditions of the vital force are chemical forces.” — p. 8.

“ As, in the closed galvanic circuit, in consequence of certain changes, which an inorganic body, a metal, undergoes when placed in contact with an acid, a certain something becomes cognizable by our senses, which we call a current of electricity ; so, in the animal body, in consequence of transformations and changes undergone by matter previously constituting a part of the organism, a certain phenomena of motion and activity are perceived, and these we call life, or vitality.

“ The electrical current manifests itself in certain phenomena of attraction and repulsion, which it excites in other bodies naturally motionless, and by the phenomena of the formation and decomposition of chemical compounds, which occur everywhere, when the resistance is not sufficient to arrest the current.

“ It is from this point of view, and from no other, that chemistry ought to contemplate the phenomena of life. Wonders surround us on every side. The formation of a crystal, of an octahedron, is not less incomprehensible than the production of a leaf or of a muscular fibre ; and the production of vermilion, from mercury and sulphur, is as much an enigma as the formation of an eye from the substance of the blood.

“The first conditions of animal life are nutritious matters and oxygen, introduced into the system.” — p. 11.

We have extracted thus freely in order to exhibit, in the author's own language, an outline of the principles, on which he explains the multifarious and complicated functions of animal and vegetable life. The whole work is but an elucidation of these principles; an attempt to show, in detail, in what manner the vital phenomena are produced by changes in the composition of the several parts of the body. Not only respiration, and the production of animal heat, but digestion, assimilation, and secretion, all the changes of growth, and supply, and wasting, and even the phenomena of disease, and the operation of medicines, are traced directly to chemical action. The living body is a mere alembic, or, more properly, a miniature laboratory, in every part of which the intricate processes of analysis and combination are carried on at the same moment of time.

This attempt at chemical physiology is not altogether new. Chemists have often busied themselves with the products of organized beings, and to very good effect, although they have hitherto found much, that their researches could not fully reach. Modern chemists have, in general, despaired of becoming acquainted with the properties of these products by a mere knowledge of their ultimate constituents, and have directed their attention more to the nature and characteristics of the compounds themselves, or *proximate principles*. Professor Liebig, on the other hand, looks upon these with no other interest, than to ascertain the quantity of carbon, oxygen, &c. they contain, for the supply of the several organs. For *qualitative observations*, as he terms the inquiries into the character and uses of the proximate organic compounds, he has no respect; nor much, indeed, for the understanding of those who make them.

“The numberless qualitative investigations of animal matters, which are made, are equally worthless for physiology and for chemistry, so long as they are not instituted with a well-defined object, or to answer a question clearly put.

“If we take the letters of a sentence which we wish to decipher, and place them in a line, we advance not a step towards the discovery of their meaning. To resolve an enigma, we must have a perfectly clear conception of the problem. There are many ways to the highest pinnacle of a mountain; but

those only can hope to reach it who keep the summit constantly in view. All our labor and all our efforts, if we strive to attain it through a morass, only serve to cover us more completely with mud; our progress is impeded by difficulties of our own creation, and at last even the greatest strength must give way when so absurdly wasted." — p. 125.

His way to the pinnacle is up the heights of *Quantitative Analysis*. He ascertains the exact proportional quantity of carbon, hydrogen, oxygen, and nitrogen, in muscular flesh, in the skin, in the tendons, in the brain; he does the same with the several parts of the blood, and the matters received into it, and the matters which go out of it; and thus he learns what portion is fitted to nourish each part, what changes they undergo in the process of assimilation and of rejection, and what particles are thrown out at last as inappropriate, or as having performed their office. All is pure chemistry, — changes in the composition of the ultimate particles of matter.

But it is time to inquire into the truth of all this. What is the evidence, that the functions of life are mere processes in chemical composition and analysis? To those who have given the least attention to the subject, the question brings its own answer. There is so much of absurdity in the mere statement of the matter, especially when viewed in its details, that we seem almost called upon to furnish proof, that we have stated them fairly, rather than to show how unfounded such views really are. And yet these views have attracted attention and applause. There is something very taking, in fancying that we have revealed to us the secret workings of Nature in her most complicated operations. But Nature is not ordinarily so lavish of her secrets.

We have already mentioned briefly some peculiarities of organic chemistry, in contradistinction from the actions of mere affinity in inanimate matter; and all these peculiarities indicate a difference in the nature of the cause, by which the actions are produced. In ordinary chemistry, the elementary substances, although not numerous in comparison with the almost infinite variety of objects in nature, are many in comparison with the much smaller number in organized matter. Their combinations are simple; only two or three elements commonly, and rarely four, entering into one composition; and these in very few proportions between the same ele-

ments. In organized matter, it is extremely rare to have less than three elements in a compound ; and these are united in every conceivable variety of proportions, thus giving rise to the innumerable products of animal and vegetable life, so far as their peculiarities depend on differences of composition.

These compounds, as we have said, cannot be reproduced, nor imitated. We can unite some of the same elements, but the results are widely different ; we can combine oxygen with hydrogen, but we obtain only water in one proportion, and an oxide of hydrogen in another ; oxygen and nitrogen we may unite in five different proportions, and yet we produce only oxides or acids ; carbon and oxygen, give us but one oxide and an acid ; nitrogen and hydrogen give us ammonia, and carbon and hydrogen furnish the inflammable gases, naphtha, &c. By a union of three of the elements, we get a nitrate or a carbonate of ammonia. We have thus enumerated all or nearly all the artificial compounds of which these four elements are susceptible, and no one of them bears the slightest resemblance to any of the combinations of the several elements in organized matter, by which we are surrounded at every turn. Mr. Abernethy was accustomed, in his lectures, to describe the inability of chemistry to imitate the actions of organized bodies in his emphatic manner. "Gentlemen," said he, "the chemists may tell us of what the body is composed, and of what the fæces that are thrown out of the body are composed, how much oxygen they contain, and how much nitrogen, and how much carbon ; but, Gentlemen, all the chemists in the world can't make one."

But if it were possible for us to produce the identical composition and form, it would still not be the same living thing. Organization is the effect of life, not its cause. And, since living beings are no longer created anew by direct power, life itself can only be exhibited by transmission from one individual to another of the same kind. When life has departed, the organization may, for a moment at least, remain the same ; but no power on earth can reanimate it.

Neither does the organization itself remain permanent after the loss of its vitality. Some parts are decomposed very speedily after death, and give up their constituents to their natural affinities ; others retain more or less of their

composition for a longer period, sometimes for many years ; but in all the tendency to decay begins immediately, and sooner or later the decomposition is complete. It may in some cases be retarded, indeed, by the absence of heat and air and moisture ; but these very circumstances, which favor the decomposition, are precisely those that were necessary to the growth and sustenance of these parts while life was present. How unlike all this is to the action of chemical affinity, where the composition remains permanent, so long as the affinities and the temperature are the same.

There is, it is true, much of chemical action in the living body ; but, it is always in subjection to the vital power. It is here the same as with the mechanical forces. In the motions of a joint, for example, the contraction of the muscles is a process peculiar to life ; the effect produced, in the extent and velocity of the motion, is precisely the same as if the moving power were mechanical, while the intervening parts, the tendons, ligaments &c., partake partly of living, and partly of mechanical properties. So it is with chemistry. Just so far as the chemical affinities can be made to subserve the purposes of the living economy, they are employed ; whenever they are at variance with those purposes, they are either modified or suspended. They resume their sway only when life is departed. In the living body chemistry is always the servant, never the master.

This brings us to the point at which our opinions are most directly opposed to those of our author. Notwithstanding all that he says about the influence of a vital force, he seems to us to make all the principal operations of the living body to depend upon chemical action, as the chief moving cause. We say, on the contrary, that there is naturally no purely chemical action, that is not the effect of disease ; and none can be excited without producing disturbance or destruction to the functions of the part implicated in it. In digestion, for example, the solution of the food into chyme is effected by a peculiar fluid, produced alone by a living organ, and in a peculiar manner ; and it is not until the powers of the stomach are greatly impaired, that the phenomena of pure chemistry are exhibited. Our author, indeed, claims digestion as altogether a chemical process, analogous to fermentation, and discards, very positively, all idea of the influence of vitality. In his first Report, he says ;

“ We should not permit ourselves to be withheld, by the idea of a *vital principle*, from considering, in a chemical point of view, the process of transformation of the food, and its assimilation by the various organs. This is the more necessary, as the views hitherto held, have produced no results, and are quite incapable of useful application.” — p. 113.

And in the present work ;

“ The most decisive experiments of physiologists have shown, that the process of chymification is independent of the vital force ; that it takes place in virtue of a purely chemical action, exactly similar to those processes of decomposition or transformation, which are known as putrefaction, fermentation, or decay (*eremacausis*).” — p. 104.

Now every practical physician knows full well, that the slightest appearance of fermentation, in the stomach, is a sure indication of disease. The solution of the food into chyme, which Professor Liebig appears to regard as the whole of digestion, is but a modified chemistry, at most, executed by agencies that can only be produced by living organization. And when we advance to the higher parts of the process, the separation of the nutritious from the refuse portions of the food, — the constitution and absorption of the chyle, the necessary influence of a vital power is still more observable.

The saliva has long been known to exert an important influence in promoting digestion. But its precise mode of action, as explained by our author, we believe will be new to most of our readers.

“ In the action of the gastric juice on the food, no other element takes a share, except the oxygen of the atmosphere and the elements of water. This oxygen is introduced directly into the stomach. During the mastication of the food, there is secreted into the mouth from organs specially destined to this function, a fluid, the saliva, which possesses the remarkable property of enclosing air in the shape of froth, in a far higher degree than even soap suds. This air, by means of the saliva, reaches the stomach with the food, and there its oxygen enters into combination, while its nitrogen is given out through the skin and lungs. The longer digestion continues, that is, the greater the resistance offered to the solvent action by the food, the more saliva, and consequently the more air, enters the stomach. Rumination, in certain graminiferous [herbivorous?] animals, has plainly for one object a

renewed and repeated introduction of oxygen; for a more minute mechanical division of the food only shortens the time required for solution." — p. 108.

How causeless, then, the anxiety of many a tender mother, lest her precious little one should get "wind in the stomach." An easy remedy for indigestion! A little practice will enable a man to suck in as much air as he lists; or a stomach-pump, when he is oppressed, will distend him to his heart's content.

There is probably no other of the functions of animal life, that approaches so near to a purely chemical operation as respiration. The change in the air respired is entirely chemical, and may well be attributed to affinity, except that some other influence is necessary to enable oxygen to combine with either carbon or hydrogen at so low a temperature. As the blood alone can furnish the materials for the change in the air, it is an obvious and necessary inference, that there is also a corresponding change in its composition; although analysis has never been able to detect any such difference between the venous and arterial blood. Whether this change consists in the absorption of oxygen into the blood from the air, or discharging into the air carbon and perhaps hydrogen, is not fully settled. Most modern physiologists incline to the latter opinion; our author, as we shall see presently, adheres to the former.

Carbonic acid is made up of oxygen and carbon, in such proportions, that any given quantity of it (by measure) contains exactly as much oxygen as the same measure of pure oxygen gas. In ordinary respiration, the bulk of the air is very little altered; that is, the quantity of carbonic acid that is found in the respired air, is very nearly the same with that of the oxygen gas that is lost; there is a slight deficiency. Hence it is inferred, that the effect of respiration is to take out of the blood a portion of its carbon, by combination with the oxygen of the air; and the deficiency is accounted for by supposing that some hydrogen is removed in the same manner, giving rise to a portion of the moisture always found in respired air. There are other reasons for this opinion, in the absence of any known sufficient power of attraction to fix the oxygen in the blood, and the difficulty of accounting for the transmission of the carbonic acid if formed elsewhere; but we will not dwell upon them at present.

Whatever may be the nature of the change in the blood, it is evident that it is not the alteration of its character as a chemical compound, that renders the change so essential to life. The useful elements of the blood are impaired indeed, but not all exhausted, when they are brought back to the lungs to be renewed and revived. A small portion (very small in proportion to the whole mass) is cast off, or received. If this were only a change of elements, a failure to accomplish the change would indeed diminish the power of the blood to carry on its functions, and ultimately destroy life. But the effect would be gradual, like the slow decay of the body from the abstraction of food. How far this is from being the case, is well known. As soon as blood which has but once passed through the lungs and heart unchanged by respiration, is thrown into any part of the body, that part is paralyzed; as soon as it reaches the brain, life is destroyed. The whole system is poisoned, and inevitable death is the immediate consequence.

Professor Liebig takes a very different view of the whole matter. With him, respiration is but a slow combustion. Oxygen is absorbed from the air into the blood, to support this combustion, and the different kinds of food, received into the body and digested, supply the fuel. These meet in the course of the circulation, and combine; and the carbonic acid and water which proceed from the combination, are carried off by the lungs; with processes and results precisely analogous to those of ordinary combustion, only that they are produced more slowly. Thus the lungs are both the hearth for the supply of air, or its oxygen, and the chimney for carrying away the smoke; while the stomach brings in the necessary chips and coal to keep up the flame. Not that the food is introduced for the sole purpose of fuel. It performs the various offices of nutrition; and in the transformations which it undergoes while thus employed, and after those offices are performed, it becomes united to oxygen in the same manner as if it were introduced only for that object.

We shall not stop here to examine this theory in the general, but shall consider it rather in some of its applications to the several functions. For, with our author, the combination of oxygen is the chief chemical agency, which carries on so many of the processes of the living body. The first of these that we shall notice, is the production of *Animal Heat*.

It is well known, that all animals preserve a temperature of body considerably above that of the atmosphere in which they live, and that this temperature is nearly uniform at all times, whatever may be that of the air around them. This, of course, creates a great and constant demand for heat ; and the question is, How is this demand supplied ? Professor Liebig follows the opinion of those who believe, that the heat is all produced by the slow combustion of respiration. “ The animal body,” he says, “ is a heated mass, which bears the same relation to surrounding objects as every other heated mass. It receives heat when the surrounding objects are hotter, it loses heat when they are colder, than itself.”— p. 18.

This declaration should not be received without considerable qualification. There is much reason to believe, that the living body has power, to a very considerable extent, of resisting the introduction of heat ; and it is not improbable that it has a similar power of preventing its escape, in a limited degree. The cold limbs of a person much exhausted by disease (cholera, for example,) cannot be made to receive the heat of a warm bath, unless the languid powers of life are at the same time aroused ; but, if he die in the bath, they soon acquire the temperature of the water. But this power, whatever it may be, is of small extent ; and enough of demand for heat remains, to renew the question, How is it supplied ? Professor Liebig answers ;

“ This high temperature of the animal body, or, as it may be called, disengagement of heat, is uniformly, and under all circumstances, the result of the combination of a combustible substance with oxygen.

“ In whatever way carbon may combine with oxygen, the act of combination cannot take place without the disengagement of heat. It is a matter of indifference whether the combination take place rapidly or slowly, at a high or at a low temperature ; the amount of heat liberated is a constant quantity.

“ The carbon of the food, which is converted into carbonic acid within the body, must give out exactly as much heat as if it had been directly burnt in the air or in oxygen gas ; the only difference is, that the amount of heat produced is diffused over unequal times.”— p. 17.

“ To make use of a familiar, but not on that account a less just illustration, the animal body acts, in this respect, as a furnace, which we supply with fuel. It signifies nothing what intermediate forms food may assume, what changes it may undergo

in the body, the last change is uniformly the conversion of its carbon into carbonic acid, and of its hydrogen into water; the unassimilated nitrogen of the food, along with the unburned or unoxidized carbon, is expelled in the urine or in the solid excrements. In order to keep up in the furnace a constant temperature, we must vary the supply of fuel according to the external temperature, that is, according to the supply of oxygen.

“In the animal body, the food is the fuel; with a proper supply of oxygen we obtain the heat given out during its oxidation or combustion. In winter, when we take exercise in a cold atmosphere, and when consequently the amount of inspired oxygen increases, the necessity for food containing carbon and hydrogen increases in the same ratio; and by gratifying the appetite, thus excited, we obtain the most efficient protection against the most piercing cold. A starving man is soon frozen to death; and every one knows, that the animals of prey in the arctic regions far exceed in voracity those of the torrid zone.”— p. 18.

In one particular, at least, the illustration fails. The interior of the assumed furnace is no hotter than the rest of the building. It is a well-established fact, that the temperature of the lungs is no higher than that of the other parts of the body. This difficulty has long been perceived. More than sixty years ago, Dr. Crawford published an elaborate treatise on the subject, and endeavoured to remove the objection by showing, that arterial blood has a greater capacity for heat than venous, and absorbs enough in the lungs, without increase of temperature, to supply the wants of the body. But his explanation was never very generally received, partly because it was unsatisfactory, and partly because his book was too dull to be read. Professor Liebig gives a different solution. His combustion takes place, not in the lungs chiefly, but over the whole body. The red globules of the blood are his “carriers of oxygen,” and they transport it to the parts where it is wanted, and there the fire is kindled, and the carbonic acid is formed. But how does this extra proportion of oxygen get into the blood? And how does the carbonic acid get back to the lungs to be discharged? Easily enough; they are both carried by the iron in the blood!

“According to the researches of Denis, Richardson, and Nasse (*Handwörterbuch der Physiologie*, vol. i., p. 138), 10,000 parts of blood contain 8 parts of peroxide of iron. Consequently, 76,800 grains (10 lbs. Hessian) of blood contain 61·44 grains

of peroxide of iron, in arterial blood, = 55·30 of protoxide in venous blood.

“ Let us now assume, that the iron of the globules of venous blood is in the state of protoxide. It follows, that 55·30 grains of protoxide of iron, in passing through the lungs, take up, in one minute, 6·14 grains of oxygen (the quantity necessary to convert it into peroxide). But since, in the same time, the 10 lbs. of blood have taken up 12 grains of oxygen, there remains 5·86 grains of oxygen, which combine with the other constituents of the blood.

“ Now, 55·30 grains of protoxide of iron combine with 34·8 grains of carbonic acid, which occupy the volume of 73 cubic inches. It is obvious, therefore, that the amount of iron present in the blood, if in the state of protoxide, is sufficient to furnish the means of carrying or transporting twice as much carbonic acid as can possibly be formed by the oxygen absorbed in the lungs.” — p. 261.

All this is doubtless proved ; that the iron actually exists in one state in venous blood, and in a different state in arterial blood. Not in the least, gentle reader. It is merely known, that a very small quantity of iron can with difficulty be detected in the blood, by the nicest manipulations ; and all the chemists, who have found it, and ascertained its state of combination, agree in representing it as the peroxide, without reference to the kind of blood. It is not even known, except by inference, that there is any difference of composition between arterial and venous blood. But does not the color of the two oxides correspond to that of the two kinds of blood ? Not at all. And yet we are told, in the very next breath, that

“ The hypothesis, just developed, rests on well-known observations, and, indeed, explains completely the process of respiration, as far as it depends on the globules of the blood.” — p. 262.

If such are the important offices of iron, it becomes an object of interest to ascertain what quantity is contained in the blood. Without going at length into this question, it is enough, for the present purpose, to say, that the authorities, quoted by Dunglison in his “ *Physiology*,” would not make the whole amount to more than 80 grains of the peroxide in 30 pounds of blood ; which Dr. Dunglison considers as

a very large allowance for a man of 150 pounds' weight. Eighty grains of the peroxide contain 24 grains of oxygen and 56 of iron; about as much iron as is contained in one sixpenny cut nail, in the whole human body. Our author estimates it higher, and supposes that 61·44 grains of the peroxide, equal to 43 grains of iron, pass through the heart every minute, and follows the supposition with a numerical calculation to show, that this is twice as much as is needed to account for the phenomena. There are cases, however, in which a little common sense is of more worth than a great deal of calculation. It is often said, that figures cannot lie; and true mathematical demonstration is doubtless the very highest kind of evidence. But there is scarcely any basis of reasoning more liable to illusion and error, than numerical calculations founded on insufficient and uncertain data.

Let us next inquire, what amount of fuel is supplied by the blood, to combine with this oxygen, and thus keep up a uniformity of temperature in all varieties of climate and season. Our author answers the question.

“ From the accurate determination of the quantity of carbon daily taken into the system in the food, as well as of that proportion of it which passes out of the body in the fæces and urine, unburned, that is, in some form in which it is not combined with oxygen, it appears that an adult, taking moderate exercise, consumes 13·9 oz. of carbon daily.” — p. 13.

Fourteen ounces of charcoal, to make fire enough to keep a man warm twenty-four hours in a winter's day! Here, too, we have a calculation to show, that this is more than sufficient; although we fancy it must require an apparatus, more perfect even than a Nott's stove, or a Stimpson's range, to develop so much heat.

“ According to the experiments of Despretz, 1 oz. of carbon evolves, during its combustion, as much heat as would raise the temperature of 78·15 oz. of water at 32° to 212° , that is, by 180 degrees; in all, therefore, $78\cdot15 \times 180^{\circ} = 14067$ degrees of heat. Consequently, the 13·9 oz. of carbon, which are daily converted into carbonic acid in the body of an adult, evolve $13\cdot9 \times 14067^{\circ} = 195531\cdot3$ degrees of heat. This amount of heat is sufficient to raise the temperature of 1 oz. of water by that number of degrees, or from 32° to $195563\cdot3^{\circ}$; or to cause 67·9 lbs. of water at 32° to boil; or to heat $184\cdot3$

lbs. of water to 98.3° (the temperature of the human body); or to convert into vapor 11.4 lbs. of water at 98.3° ." — p. 32.*

If any of our readers are disposed to test the sufficiency of this amount of heat, let them fill a leathern bag of the size and shape, as nearly as may be, of the human body, with the weight of a man (150 lbs.) of water heated to 98 degrees, and hang it exposed to the air, where the thermometer stands at 32 degrees. To render the experiment complete, the leather ought to be porous, so as to allow of a transudation equal to the transpiration through the skin, and the whole to be covered, to represent the clothing. As the water cools, draw off a portion, and pour in more of the same temperature; and see how long the 184.3 lbs. will sustain the whole mass of 150 lbs. at the original degree of heat. If twenty-four hours, then the calculation exhibits heat enough for a man under similar circumstances. If not, the deficiency in the time marks the deficiency of heating power. For ourselves, we need neither calculation nor experiment to satisfy us, that 14 ounces of charcoal and a sixpenny nail would hardly suffice to save us from freezing.

By far the most valuable portion of this work is the part on the *Metamorphosis of Tissues*. By an extensive analysis of the tissues, which enter into the structure of the several parts of the animal body, and of many of the substances which are used for its nourishment and growth, the curious and interesting fact is elicited, that the same compounds are found in both. In regard to animal food, there is nothing surprising in this; for we should naturally expect to find a similar composition in the flesh of different animals. But the composition, as well as texture and appearance of vegetables, is so unlike that of animals, that there has, heretofore, been a difficulty in understanding how herbivorous animals obtain some of the elements of their structure. The researches of Professor Liebig show, that many nutritious vegetables contain, though in much smaller proportions, all the elementary principles essential to the animal body, and

* In the New York edition, copied from the English, the calculation makes the quantity of heat sufficient to heat 370 lbs. of water to 98 degrees. The editor of the Cambridge edition finds the calculation erroneous, and corrects it as in the text. But even this larger quantity, we apprehend, would leave a large portion of the twenty-four hours without any heat above that of the surrounding air.

he obtains them in precisely the same state of combination. Thus vegetable fibrine, albumen, gluten, and caseine have the same composition, as those obtained from animal products. It may, perhaps, admit of question, whether they actually exist, ready-formed in the vegetable structure, or enter into this combination during the decomposition of the analysis. And it matters not which it is. In either case, the elements are there, and show a readiness to enter into the relations which they are to hold in the animal economy.

It is easy to see that these facts, judiciously applied, may be of important use in explaining many of the phenomena of nutrition and assimilation. Our author, we think, often applies them extravagantly. He assumes, that identity of composition or an approximation to it, is necessary to render a substance nutritive to any particular organ or structure. Hence he infers, that one sort of food is good for the formation of muscular fibre, another for fat, another for bile, and another for brain. Now we see no evidence or probability of all this. On the contrary, we believe that every part selects just those portions of matter which are required for its own purposes, and in such proportions as its own demands call for, without the slightest reference to their proportion in the articles from which they are taken. We have already seen, that certain grasses will take siliceous matter, and other plants potash, even from the glass vessels in which they are growing. The flesh of animals fed on hay, with only one and a half per cent. of nitrogen, contains as much of that element in its composition, as that of the carnivora, whose food contains fifteen per cent. of it ; and we have no doubt, that beef fed on grass and Indian corn, substances in which the proportion of nitrogen is so small as to be detected with difficulty, will be found to contain as much as that fed on grains which furnish the most of it. Sugar contains no nitrogen ; and yet the negroes employed in the manufacture are said to thrive during the sugar-harvest more than at any other time, although their work is more laborious.

All that is indispensable, is that a sufficient supply of all the essential elements should be accessible to the proper organs, and in a form to be rendered available. And this is indispensable ; hence, we see how a soil may become barren by the exhaustion of some one of its elements, while still rich in others, or barren to one kind of growth, and still

fruitful in others; as was shown in the former Report. We see, too, how it is that a certain proportion of animal food is essential to the full developement of the mental and physical energies of men. The digestive organs of herbivorous animals are fitted for the reception of large quantities of food, and they require much time to eat and digest it, in order to enable them to extract from it the requisite quantity of nitrogen. Those organs in man are more restricted; and, unless the limited amount of food, which they are adapted to receive, contains more nitrogen than is found in mere vegetable food, the vigor of his animal powers must be diminished by a deficiency of the necessary elements of his composition. A man must have the stomach of an herbivorous animal, before he can live, and thrive, upon the food of one.

Professor Liebig divides all the food into two classes: *nitrogenized* and *non-nitrogenized*; the first constitute the *elements of nutrition*; the second the *elements of respiration*. The former enter into the structure of the organs, the latter serve the direct purpose of fuel, to feed the perpetual fire; which burns so constantly within, that if these elements fail, the other must supply the deficiency, and the body preys upon its own organs. To guard against such a misfortune, a stock of fuel is laid up in the bodies of men, and some other animals, in the form of fat. This is formed out of the *non-nitrogenized* part of the food, and accumulates in those who take little animal food, and are confined from the fresh air, so as not to imbibe a sufficient quantity of oxygen. We make the following extract for the especial benefit of a friend, who will be glad to learn that his brisk exercise on the hill-top is so favorable to his coveted *reduction*, and that he has only to add a larger allowance of good beef and mutton to his dinner, to insure all that he can desire.

“The production of fat is always a consequence of a deficient supply of oxygen, for oxygen is absolutely indispensable for the dissipation of the excess of carbon in the food. This excess of carbon, deposited in the form of fat, is never seen in the Bedouin, or Arab of the desert, who exhibits with pride to the traveller his lean, muscular, sinewy limbs, altogether free from fat; but in prisons and jails it appears as a puffiness in the inmates, fed, as they are, on a poor and scanty diet; it appears in the sedentary females of Oriental countries; and finally, it is produced under the well-known conditions of the fattening of domestic animals.

"The formation of fat depends on a deficiency of oxygen ; but in this process, in the formation of fat itself, there is opened up a new source of oxygen, a new cause of animal heat." — p. 85.

This theory explains to us how the *nitrogenized* roast beef and porter of old England should produce such lean sinewy frames, while their *non-nitrogenized* soup-fed neighbours across the Channel, are so fat, lusty, and lazy ! Unfortunately for its stability, however, there is in Bengal an experiment, that tests its correctness on a large scale. Two classes of people there live together side by side ; the one (the Mohammedans) live chiefly, and to the full extent of their ability, on high-seasoned animal food, the other (the Hindoos) eat only vegetables, mostly rice which furnishes little or no nitrogen. The habits of a great portion of them are in other respects much alike, for both are poor and compelled to labor. The former are much the more stout and vigorous ; but the latter, especially in the active period of life, are not at all the more corpulent.

Our limits will permit us to take only a very general notice of our author's application of his theory to the processes of assimilation and absorption, or, as he terms them, *supply* and *waste*. Of absorption, as a function performing the most important office of removing the worn-out particles of matter, and cutting off dead parts, he seems to have no conception. To him it is all a chemical operation ; each particle, having lost its vitality, by its natural affinity enters into a new combination, and floats away as inorganic matter. And yet, in reality, new products are formed in the very excretions, in the urine, and in the fæces, so peculiar to organized action, that no chemist on earth can imitate them.

Professor Liebig denies to what he terms *vegetative* life, in animals as well as in plants, all control over their operations of growth and sustenance, and even derides the idea of the vessels of the latter being excited by the stimulus of substances applied to them. He overlooks, if he is not ignorant of, the property of *irritability*, or organic sensibility, and insensible contractility, so well established by Bichat and others, as universal in all living textures ; to which in reality should be attributed many of the effects on the growth of vegetables, ascribed by our author, in his former Report, to the chemical action of manures.

The powers of *animal life*, according to Professor Liebig, are derived entirely from the brain, the nerves acting the part of mere conductors, like the connecting wires of a galvanic battery, a figure which he repeatedly uses. Against this *vital force*, the chemical forces wage continual warfare. When it is in full vigor, it is able to keep them at bay, but if, from fatigue or any other cause, its vigilance flags, or its energies are impaired, they seize upon its unfortunate particles, as a watchful enemy picks up the exhausted stragglers of a retreating army, and bear them off in triumph. Respiration, that wonderful process, whose influence has ever been regarded as so benign, that “when the breath was out the man would die,” is the source of death as well as of life. For it introduces oxygen, the enemy of all peace, into the animal body; and this is carried, by the iron of the blood, into every part of the muscular system, kindling its fires in every part, and burning with such rapidity, that, whenever the fuel supplied by the *elements of respiration* fails, it devours the organs themselves. It is the very vulture of Prometheus, ever preying on the vitals of its conscious victim. In *all* chronic diseases, death is produced by no other cause, than the inability of the enfeebled system to prepare fuel for the fires of oxygen.

“In all chronic diseases death is produced by the same cause, namely, the chemical action of the atmosphere. When those substances are wanting, whose function in the organism is to support the process of respiration; when the diseased organs are incapable of performing their proper function of producing these substances; when they have lost the power of transforming the food into that shape in which it may, by entering into combination with the oxygen of the air, protect the system from its influence, then the substance of the organs themselves, the fat of the body, the substance of the muscles, the nerves, and the brain, are unavoidably consumed.

“The true cause of death in these cases is the respiratory process, that is, the action of the atmosphere.” — p. 26.

Even in consumption, then, the poor sufferer dies from excess of respiration!

The theory of acute diseases is but a modification of that of chronic.

“Every substance or matter, every chemical or mechanical agency, which changes or disturbs the restoration of the equi-

librium between the manifestations of the causes of waste and supply, in such a way as to add its action to the causes of waste, is called a *cause of disease*. *Disease* occurs when the sum of vital force, which tends to neutralize all causes of disturbance (in other words, when the resistance offered by the vital force) is weaker than the acting cause of disturbance.

"Death is that condition in which all resistance on the part of the vital force entirely ceases. So long as this condition is not established, the living tissues continue to offer resistance.

"To the observer, the action of a cause of disease exhibits itself in the disturbance of the proportion between waste and supply which is proper to each period of life. In medicine, every abnormal condition of supply or of waste, in all parts or in a single part of the body, is called disease." — p. 242.

"Now, since the phenomena of motion in the animal body are dependent on the change of matter, the increase of the change of matter in any part is followed by an increase of all motions. According to the conducting power of the nerves, the available force is carried away by the nerves of involuntary motion alone, or by all the nerves together.

"Consequently, if, in consequence of a diseased transformation of living tissues, a greater amount of force be generated than is required for the production of the normal motions, it is seen in an acceleration of all or some of the involuntary motions, as well as in a higher temperature of the diseased part.

"This condition is called *fever*.

"When a great excess of force is produced by change of matter, the force, since it can only be consumed by motion, extends itself to the apparatus of voluntary motion.

"This state is called a *febrile paroxysm*.

"In consequence of the acceleration of the circulation in the state of fever, a greater amount of arterial blood, and, consequently, of oxygen, is conveyed to the diseased part, as well as to all other parts; and, if the active force in the healthy parts continue uniform, the whole action of the excess of oxygen must be exerted on the diseased part alone.

"According as a single organ, or a system of organs, is affected, the change of matter extends to one part alone, or to the whole affected system.

"Should there be formed, in the diseased parts, in consequence of the change of matter, from the elements of the blood or of the tissue, new products, which the neighbouring parts cannot employ for their own vital functions; — should the surrounding parts, moreover, be unable to convey these products to other parts, where they may undergo transformation, then these

new products will suffer, at the place where they have been formed, a process of decomposition analogous to fermentation or putrefaction." — pp. 244, 245.

Suppuration, and consequent ulceration, nothing more nor less, than a process of decomposition, like digestion, analogous to fermentation or putrefaction !

The explanation of the action of remedies is in accordance with this view of disease. Blistering, and other counter irritation, act as a sort of diversion in favor of the *vital force*, to withdraw the attention of the enemy from the principal scene of contest.

"In cases of a different kind, where artificial external disturbance produces no effect, physicians adopt other indirect methods to exalt the resistance offered by the vital force. These methods, the result of ages of experience, are such, that the most perfect theory could hardly have pointed them out more acutely or more justly than has been done by the observation of sagacious practitioners. They diminish, by bloodletting, the number of the carriers of oxygen (the globules), and by this means the conditions of change of matter ; they exclude from the food all such matters as are capable of conversion into blood ; they give chiefly or entirely non-azotized food, which supports the respiratory process, as well as fruit and vegetables, which contain the alkalies necessary for the secretions." — p. 246.

If the bile is deficient in quantity, or in its efficiency, caffeine, asparagine, theobromine, &c. have the requisite proportions of nitrogen to replenish it, (p. 171) ; in other words, let the patient drink tea, and coffee, and cocoa, and eat asparagus. And if the mind be weak, (for the action of the mind, as we have seen, wears out the substance of the brain,) or the nervous energy be impaired, let him take, — but the author shall speak for himself ; —

"With respect to the action of the other nitrogenized vegetable principles, such as quinine, or the alkaloids of opium, &c., which manifests itself, not in the processes of secretion, but in phenomena of another kind, physiologists and pathologists entertain no doubt, that it is exerted chiefly on the brain and nerves. This action is commonly said to be dynamic, — that is, it accelerates, or retards, or alters in some way the phenomena of motion in animal life. If we reflect, that this action is exerted by substances which are material, tangible, and ponderable ; that they disappear in the organism ; that a double dose acts more

powerfully than a single one ; that, after a time, a fresh dose must be given, if we wish to produce the action a second time ; all these considerations, viewed chemically, permit only one form of explanation ; the supposition, namely, that these compounds, by means of their elements, take a share in the formation of new, or the transformation of existing, brain and nervous matter." — p. 172.

That is, as more clearly explained in the next sentence, they are "converted into constituents of brain and nervous matter."

The action of poisons is accounted for on the same general principle ; their chemical action. Prussic acid, for example, when much concentrated, is so poisonous, that a single drop, on the tongue of a kitten or a chicken, produces instant death ; and on larger animals the effect is but a little less immediate. All this is gravely ascribed to the action of the acid on the iron of the blood, by which "the globules lose their property of absorbing oxygen, and of afterwards giving up this oxygen and carrying off the resulting carbonic acid." (p. 262.)

If all this be so, well may the author exclaim,

"Respiration is the falling weight, the bent spring, which keeps the clock in motion ; the inspirations and expirations are the strokes of the pendulum, which regulate it. In our ordinary time-pieces, we know with mathematical accuracy the effect produced on their rate of going, by changes in the length of the pendulum, or in the external temperature. Few, however, have a clear conception of the influence of air and temperature on the health of the human body ; and yet the research into the conditions necessary to keep it in the normal state, is not more difficult than in the case of a clock." — p. 13.

We have purposely given our author's theory of disease and remedies almost exclusively in his own words, lest any analysis of it should have seemed to our medical readers distorted or exaggerated. We do not think so unfavorably of the understanding of any reader, medical or non-medical, as to believe that there is one among them all, who will require a word of comment to convince him how utterly unfounded and extravagant it is. If there be one such, he is past our remedy. We can only commend him to our author, and advise him to strengthen his brain with a dose of quinine or the "alkaloids of opium." Such is the splendid production upon

which the British Association felicitates itself, which a Professor of King's College counts it such a glory to have introduced into the British world, and in regard to which there is so violent a contest for the honor of assisting at its birth, on this side of the water.

We have spoken thus freely of Professor Liebig's opinions, because the questions under review are important in themselves, and because the manner in which they have been published gives them a consequence that would not otherwise belong to them. For Professor Liebig, as a chemist, we have the highest respect ; as a theoretical physiologist, we dissent from him. By his analysis of many portions of the animal body, he has rendered a great service to medical science ; and this benefit remains, however fully we may discard his opinions. The analyses given in this volume appear to have been executed not literally by himself, but by his pupils. But they were made under his observation ; and *qui facit per alium, facit per se*. In such a matter as the analysis of flesh, hair, horn, urine, and fæces, a man may well be excused for preferring, like the traveller in a storm, the "*fac-it* per alium," to the "*fac-it* per se."

The translation of neither of the Reports is what a translation ought to be. We find no great cause for complaint against the language in general, except that it is somewhat obscure ; and this, we suppose, may not be the fault of the translator. What we chiefly object to is the fact, that, in both works, the *quantities* expressed, whether in weight or measure, are not reduced to an English standard. They are left in the original designations, sometimes in French, generally in Hessian. It is true, that the foreign standard is mentioned, and a table is given at the end of the volume, by which any one, who chooses to undertake the labor, may reduce it to its equivalent value in our own language. A vocabulary and grammar would, by a little extension of the same system, enable him to read the whole work, and dispense with a translation altogether. Few readers, we believe, will take the pains to make the necessary reductions. The consequence will be, either that very indefinite notions will be obtained of the actual quantities, or they will be remembered and quoted as English weights and measures, and thus become erroneous statements of facts.

The American edition, published at Cambridge, has been

brought out under the editorial supervision of the Professor of Chemistry in Harvard College, with much assiduity and care. We are told, that many errors of the press, that are found in the English edition, have been corrected. The numerical estimates and calculations have all been revised, and some pretty essential corrections made in them. One of these, we have already noticed, in which the error more than doubled the amount of the result. Now, although we have not attached a very high degree of consequence to these calculations, as sustaining Professor Liebig's peculiar views in Physiology, we do esteem them of great value as simple expressions of interesting facts. As records of such facts they will be preserved. They will be introduced into systems of physiology, and become the ground work of arguments and reasonings. It is, therefore, of great importance, that they should correctly express the truth.

It is not necessary for us to enter into the controversy between the Cambridge and the New York editions. In our last number, we discussed at large the question of a national copyright. We need do no more now, than to allude to this case, as another striking illustration of the urgent necessity for some protection to authors abroad, to enable them to present their works to American readers, in a manner that shall be just to their reputation and satisfactory to their feelings.

ART. VIII. — *The Fountain, and other Poems*; by WILLIAM CULLEN BRYANT. New York and London: Wiley & Putnam. 1842. 12mo. pp. 100.

WE have no intention of entering upon a general examination of Mr. Bryant's poetical character. His name is classical in the literature of the language. Wherever English poetry is read and loved, his poems are known by heart. Collections of poetry, elegant extracts, schoolbooks, "National Readers," and the like, draw largely upon his pieces. Among American poets his name stands, if not the very first, at least among the two or three foremost. Some of his pieces are perhaps greater favorites with the reading public, than any others written in the United States. His "Thanatopsis," for example, is universally regarded as admirable in conception and exquisite in execution. With all thoughtful persons,